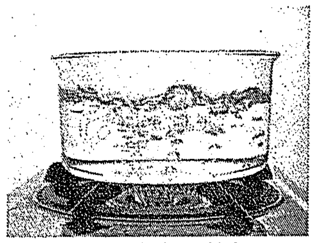
1. **25%.** A pot filled with water of 1.2 kg is put on a stove. With a heating power set to 1.25 kW, the water is heated up from 25 ^{0}C. Please use your knowledge of thermodynamics to answer the questions below.



(http://iab-sciencelab.wikispaces.com/)

(a)(7%) The first law of thermodynamics for transient processes is listed below:

$$\dot{Q}_{1\text{-}2} - \dot{W}_{1\text{-}2} + \sum \dot{m}_i h_i - \sum \dot{m}_o h_o = \dot{m}_2(u_2 + \tfrac{1}{2}V_2^2 + gZ_2) - \dot{m}_1(u_1 + \tfrac{1}{2}V_1^2 + gZ_1) \quad \text{(Eq. 1.1)}$$

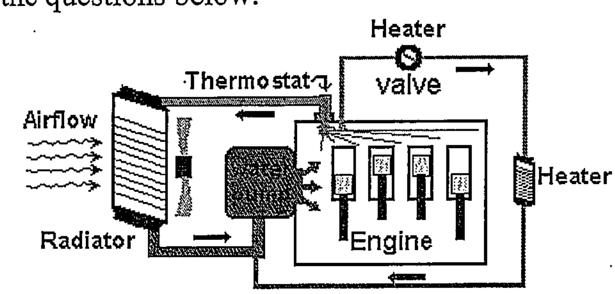
$\dot{Q}_{1\text{-}2}$ and $\dot{W}_{1\text{-}2}$ are heat transfer into the system and work done by the system during the transient process from state 1 to 2. $\dot{m}$ and h are the mass flow rate and enthalpy. The subscript i and o represent for inlet and outlet of the system. u, V, and Z represent the internal energy, velocity, and elevation. You are asked to determine the time taken to heat the water from 25 ^{0}C to a certain temperature degree, how do you ***simplify*** Equation 1.1, which allows you to deal with the problem?

(b)(7%) How do you further relate your simplified equation in (a) to the water temperature? The purpose is to make this simplified equation in (a) as a function of the water temperature.

(c)(7%) If the specific heat (C_p) of water is known (4.18 kJ/kg-K) for the working temperature, how do you rearrange your simplified equation in (b) to calculate the total time taken to heat up the water?

(d)(4%) After how long time do you expect the water temperature to be 100^{0}C?

2. 25%. An engine coolant at 60 ^{0}C enters an engine and removes engine heat around 19 kW when leaving the engine, the coolant cannot exceed a specific temperature. Please use your knowledge of thermodynamics to answer the questions below:



(http://intecsciwri.wikidot.com/internal-combustion-engine)

(a)(7%) You are asked to determine the required mass flow rate of the coolant, how do you simplify Eq. (1.1), which allows you to deal with the problem?

(b)(7%) How do you further relate your simplified equation in (a) to the coolant temperature? The purpose is to make this simplified equation in (a) as a function of the coolant temperature.

(c)(7%) If the specific heat (C_p) of coolant is known (2.42 kJ/kg-K) for the working temperature, how do you rearrange your simplified equation in (b) to calculate the required mass flow rate of the coolant?

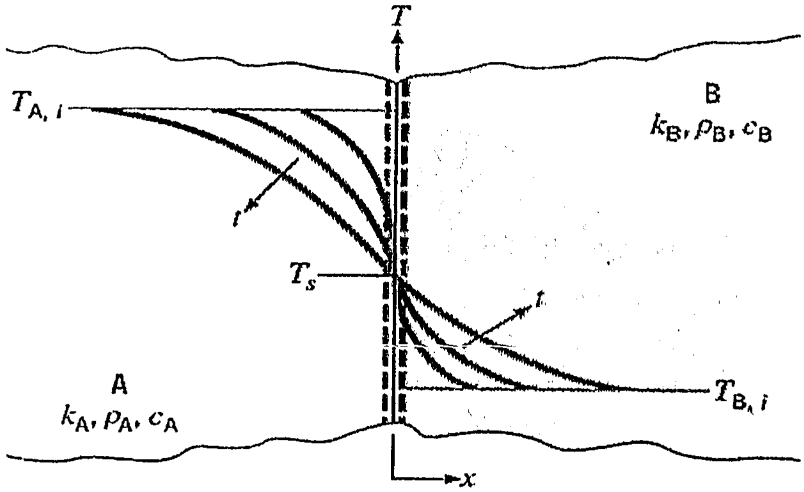
(d)(4%) What is the required mass flow rate if the coolant should come out at maximum 95 ^{0}C?

國立中山大學104學年度碩士暨碩士專班招生考試試題

科目名稱：基礎熱傳學【機電系碩士班甲組】 題號：438003

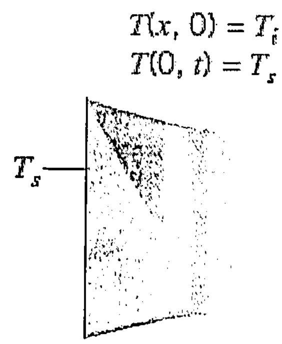
※本科目依簡章規定「可以」使用計算機（廠牌、功能不拘）

3.20%. Two semi-infinite solids A and B with uniform initial temperature $T_{A,i}$ and $T_{B,i}$ are placed side by side at x=0 from t>0 as shown in the figure. The thermal conductivity, density, heat capacity of solid A and B can be denoted as (k_A, ρ_A, c_A) and (k_B, ρ_B, c_B). The temperature profile T(x, t) is illustrated in the figure. As time t increases, the temperature difference between these two solids will decrease. The temperature T at x=0 will be independent of time t. Please calculate the temperature T at x=0.



Hint: When a single semi-infinite solid with initial condition T_i is suddenly imposed by a constant temperature T_s at x=0, the heat flux q_s', which is a function of time t, can be expressed as following equation:

$$q_s''(t) = k(T_s - T_i)/(\pi\alpha\, t)^{1/2}$$



4.(25%) Consider a two-dimensional square solid in Figure 4.1 with length defined as L and a uniform initial temperature T_0. Then the upper side is suddenly imposed by a constant temperature T_1. The steady state temperature $T(x,y)$ can be solved by the following heat equation and boundary conditions in Equation 4.1. The solution $T(x,y)$ is already given below as Equation 4.2:

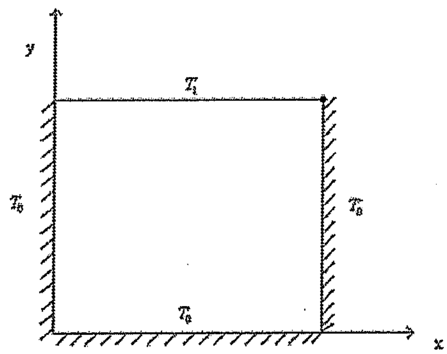


Figure 4.1

$$\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}=0 \qquad \text{(Eq. 4.1)}$$

$$BC'S: T(x,0)=T_0,\ T(0,y)=T_0,\ T(L,y)=T_0,\ T(x,L)=T_1$$

$$\Rightarrow \frac{T(x,y)-T_0}{T_1-T_0}=\frac{2}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^{n+1}+1}{n}\cdot\sin\left(\frac{n\pi x}{L}\right)\cdot\frac{\sinh\left(\frac{n\pi y}{L}\right)}{\sinh(n\pi)} \qquad \text{(Eq. 4.2)}$$

(a)(10%) Now please consider a flow inside a channel. The representative cross section is shown in Figure 4.2. The channel has a constant cross-sectional area along z axis. The cross section is a square with length L. Initially, the flow inside the channel is stationary. Then the upper side of the channel is moving at a constant velocity U_1 along z axis while the other three side walls remain stationary.

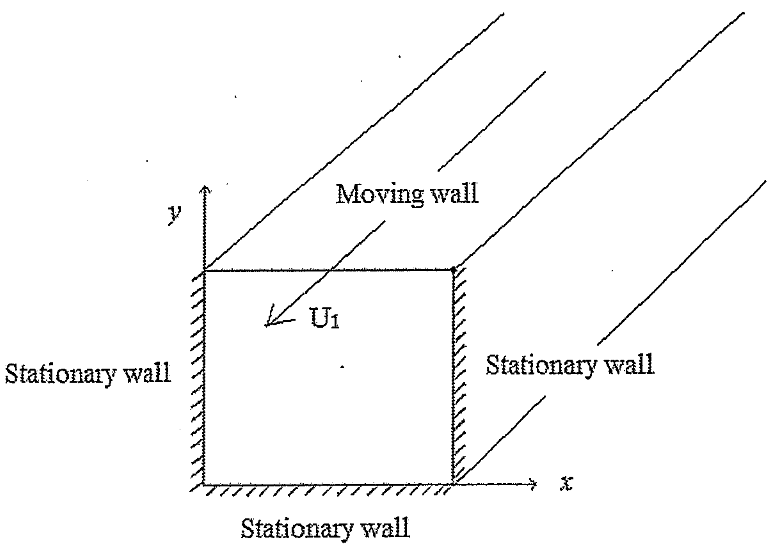


Figure 4.2

The z momentum equation of Figure 4.2 is given as Equation 4.3:

$$\frac{\partial u_z}{\partial t}+u_x\frac{\partial u_z}{\partial x}+u_y\frac{\partial u_z}{\partial y}+u_z\frac{\partial u_z}{\partial z}=-\frac{\partial p}{\partial z}+\mu(\frac{\partial^2 u_z}{\partial x^2}+\frac{\partial^2 u_z}{\partial y^2}+\frac{\partial^2 u_z}{\partial z^2}) \qquad \text{(Eq. 4.3)}$$

Assume the flow is fully-developed in z direction, steady, incompressible, laminar, and **WITHOUT** pressure gradient. Also, u_x and u_y in x and y direction can be neglected. Please simplify Equation 4.3.

(b)(5%) Please list velocity boundary conditions of u_z in z direction for these four side walls.

(c)(10%) Comparing your results of (a) and (b) to Equation (4.1), then please utilize Equation (4.2) to give solution of $u_z(x,y)$ of Figure 4.2.

5.(5%) The thermal resistance is defined as the ratio of the temperature difference to the heat transfer rate. Similarly, flow resistance of a pipe flow can be defined as the ratio of the pressure drop to the volume flow rate. The volume flow rate Q can be obtained by pressure drop Δp of the pipe over a distance L, fluid viscosity μ, and the diameter R of the pipe. can be derived as following:

$$Q=\frac{\pi R^4 \Delta p}{8\mu L}$$

The flow resistance F then becomes:

$$F\equiv\frac{\Delta p}{Q}=\frac{8\mu L}{\pi R^4} \qquad \text{(Eq. 5.1)}$$

Recently, the mayor of Taipei City, Ko Wen-Je (柯文哲), has questioned the design of the underground passage of the Taipei Dome (台北巨蛋). From the entrance to the exit, the diameter of the underground passage varies from 80 to 6 meter. Please comment how his concern comes from by Equation 5.1. Can Equation 5.1 really applied to this design problem? Why?